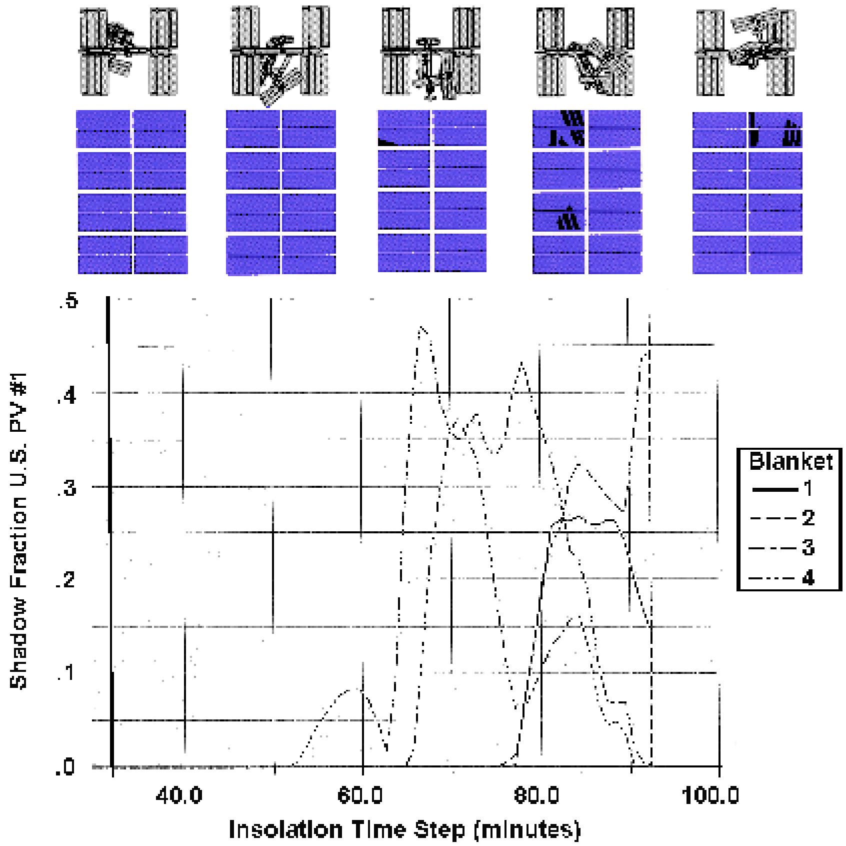
Analysis of Shadowing Effects on Spacecraft Power Systems

As part of an ongoing effort within the NASA Lewis Research Center's Power Systems Project Office to assist in the design and characterization of future space-based power systems, analyses have been performed to assess the effects of shadowing on the capabilities of various power systems on the International Space Station and the Russian MIR.

Spacecraft are typically powered with solar energy devices (such as photovoltaic solar arrays or solar dynamic mirrors). So that these devices can be designed to adequately meet the power requirements of the vehicle, it is necessary to obtain an accurate estimation of the amount of solar energy impinging on the solar collectors. This amount is affected not only by how well the solar collector is pointing at the Sun, but also by how much of the solar collector is shadowed by other parts of the spacecraft. Factors that add to the complexity of analyzing shadowing include the number of spacecraft hardware geometric configurations, yearly and daily orbital variations in the vehicle attitude due to drag area or environmental conditions, orbital maneuvers for reboost, collision avoidance, communications coverage contingency scenarios, payload pointing requirements, and improved power production and rendezvous/docking with other vehicles (which may require the reorientation of the solar energy collectors to avoid impingement with the maneuvering-jet plume).

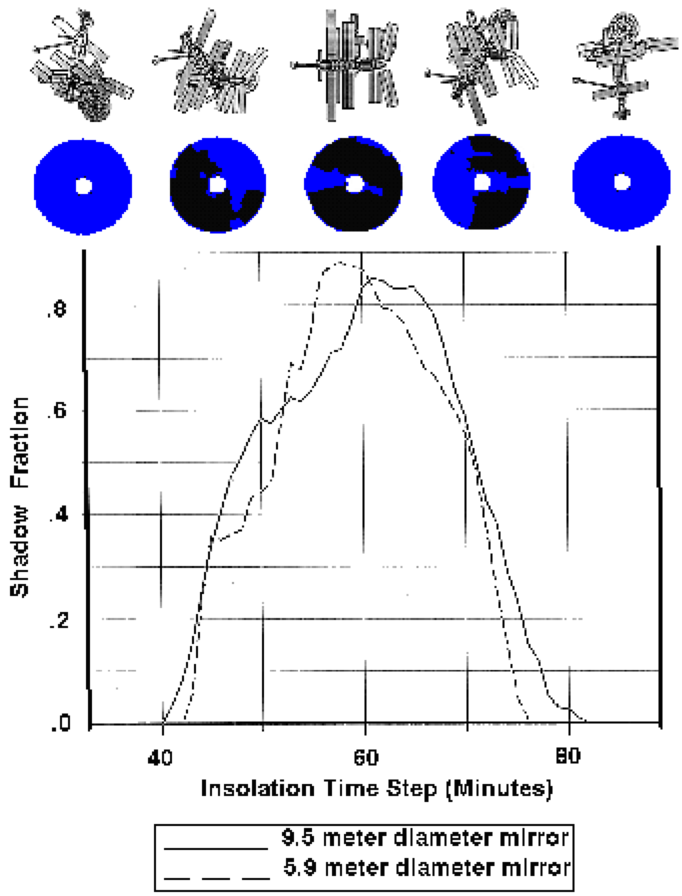
The shadowing software developed for this analysis is described in reference 1, and some typical analyses are shown in references 1 and 2. The software was integrated with a power system analysis computer program that is documented in reference 3.

The following figure shows the International Space Station vehicle geometry, shadow patterns, and shadow fractions for various time steps through the sunlit phase of the orbit. In these cases, shadowing is a transient phenomena with specific solar array blankets losing nearly 50 percent of their incident solar energy. Although the data shown are for just one U.S. photovoltaic module with 4 solar array units, there are 28 separate solar array units on the International Space Station. The geometry images assist in determining the primary cause of shadowing, in this case, the Russian Science Power Platform solar array units. The software utilizes the spatial shadow information for power calculations because the connectivity of the solar array blankets causes the power loss due to shadowing to be greater than what would be expected from the shadowed fraction alone.



Shadowing on International Space Station U.S. Solar Arrays.

The next figure shows the geometry of the Russian MIR Space Station with the joint U.S./Russian solar dynamic power system including the shadowing images and fractions for the solar dynamic mirror. For these analyses, the mirror underwent a sizing design to determine the optimum size for use with a specific heat engine. The MIR has numerous solar arrays that are closely mounted to the pressurized modules. This makes the shadowing much greater than for the International Space Station.



Shadowing on Joint U.S./Russia MIR Solar Dynamic Flight Experiment.

References

1. Fincannon, H.J.: Analysis of Shadowing Effects on Spacecraft Power Systems. NASA TM-106994, 1995.

2. Fincannon, J.: Analysis of Shadowing Effects on MIR Photovoltaic and Solar Dynamic Power Systems. NASA TM-106940, 1995.

3. Hojnicki, J.S., et al.: Space Station Freedom Electrical Performance Model. NASA TM-106395, 1993.